REMARKS

In paragraph 6 of the Action, claims 10 and 22 were rejected under 35 U.S.C. 112, second paragraph. In paragraph 8 of the Action, claims 1-3, 6, 9, 15-17, 19 and 21 were rejected under 35 U.S.C. 102(b) as being anticipated by Mizuuchi '495. In paragraph 9 of the Action, claims 1, 2, 5, 15 and 16 were rejected under 35 U.S.C. 102(b) as being anticipated by Mizuuchi '515. In paragraph 11 of the Action, claims 8, 18 and 19 were rejected under 35 U.S.C. 103(a) as being unpatentable over Mizuuchi '495. In paragraph 12 of the Action, claims 4 and 7 were objected to as being dependent upon a rejected base claim, but were indicated allowable if rewritten in independent form.

In view of the rejections and indication of allowance, claims 1, 3-8, 10, 15, 17-20 and 22 have been amended, and claims 11-14 and 23-26 have been canceled. In view of the indication of allowance, claim 4 has been amended in independent form. Claims 1 and 15 have been amended to overcome the rejections by the prior art.

In amended claim 1, the relationship between the control layer and the ferroelectric single crystal, and features of the control layer are clarified. More specifically, "forming the control layer in the first face of the ferroelectric single crystal", "forming the first electrode on the first face", and "the control layer functions as physical hindrance for the growth of a domain inverted region to the first electrode by a larger defect density D_{cont1}" are clarified.

In amended claim 15, as in the amended claim 1, the relationship between the control layer and the ferroelectric single crystal, and the features of the control layer are clarified. More specifically, "forming the control layer in the first face of the ferroelectric single crystal", "forming the first electrode on the first face", and "the control layer functions as physical hindrance

for the growth of the domain inverted region to the first electrode by a lower degree of order of lattice points" are clarified.

In amended claims 6 and 19, as the amended claims 1 and 15, the relationship between the control layer and the ferroelectric single crystal is clarified furthermore.

In amended claims 10 and 22, a step of removing the first electrode, the second electrode and the control layer after a step of applying an electric field, is clarified.

In amended claim 5, the feature of "to out-diffuse atoms from the first face" is defined.

Claim 1 of the invention is directed to a method of forming short-period domain inverted regions in the ferroelectric single crystal in a controllable time period of application of voltage.

In this respect, the method according to amended claim 1 includes a step of forming the control layer in the first face of the ferroelectric single crystal; a step of forming the first electrode on the first face; a step of forming the second electrode on a second face; and a step of applying the electric field between the first electrode and the second electrode. Features defined in amended claim 1 reside in that "the control layer formed in the first face of the ferroelectric single crystal has a larger defect density D_{contl} than the defect density D_{ferro} of the ferroelectric single crystal other than the control layer"; and "the control layer functions as the physical hindrance for the growth of the domain inverted region to the first electrode by the larger defect density D_{contl}".

According to the above-mentioned features, since the control layer is formed just before the domain growing from the second electrode to the first electrode reaches the first electrode, a plurality of defects in the control layer becomes the physical hindrance for the growth of the domain, so that the domain can be suppressed (or completely halted) from reaching the first electrode.

As a result, the termination of spontaneous polarization of domain can be effectively suppressed in the first electrode, so that side wind of the domain is also suppressed. Herewith, even in the case of making the period of polarization inversion more short-period, it is necessary to apply a voltage for a longer time than in the conventional art. Therefore, it is possible to make the polarization inversion more short-period using a conventional apparatus without using a special expensive apparatus. Also, the polarization inverted regions can be formed without the disorder of the periodicity at the first electrode side.

Claim 15 is directed to a method of forming the short-period domain inverted regions in the ferroelectric single crystal in the controllable time period of application of voltage.

In this respect, the method according to amended claim 15 includes the step of forming the control layer in the first face of the ferroelectric single crystal; the step of forming the first electrode on the first face; the step of forming the second electrode on the second face; and the step of applying the electric field between the first electrode and the second electrode. Features defined in amended claim 15 resides in that "the control layer formed in the first face of the ferroelectric single crystal has a lower degree of order of the lattice points than that of the ferroelectric single crystal other than the control layer"; and "the control layer functions as the physical hindrance for the growth of the domain inverted region to the first electrode by the lower degree of order of the lattice points".

According to the above-mentioned features, since the control layer is formed just before the domain growing from the second electrode to the first electrode reaches the first electrode, geometrical disorder in a crystal lattice by the lower degree of order of the lattice points of the control layer becomes the physical hindrance for the growth of the domain, so that the domain

can be suppressed (or completely halted) from reaching the first electrode. As a result, the termination of the spontaneous polarization of the domain can be effectively suppressed in the first electrode, so that the side wind of the domain is also suppressed. Herewith, even in the case of making the period of the polarization inversion more short-period, it is necessary to apply the voltage for a longer time than in the conventional art. Therefore, it is possible to make the polarization inversion more short-period using a conventional apparatus without using a special expensive apparatus. Also, the polarization inverted regions can be formed without the disorder of the periodicity at the first electrode side.

In amended claims 10 and 22, "the step of removing the first electrode, the second electrode and the control layer after the step of applying the electric field" is clarified. Herewith, without damaging the functions of claims 1 and 15, the object of the invention can be obtained. Therefore, both amended claims 10 and 22 are clear.

In the Action, it was held that claims 1 and 15 do not have novelty Mizuuchi '495. Also, Examiner relates ferroelectric single crystalline films 51, 61, 62 in Mizuuchi '495 to the control layer in claims 1 and 15. However, this opinion is wrong. The ferroelectric single crystalline films 51, 61, 62 in Mizuuchi '495 are formed inside a ferroelectric single crystalline substrate 1, and not the control layer including the larger defect density than that of the ferroelectric single crystalline substrate 1, nor the control layer including the lower degree of order of the lattice points than that of the ferroelectric single crystalline substrate 1. Moreover, the ferroelectric single crystalline films 51, 61, 62 do not function as physical hindrance for the growth of the domain inverted region to a uniform electrode 53.

An object of Mizuuchi '495 is to provide (1) a method of easily forming a fine polarization inversion structure for a material which is difficult to form a fine polarization inversion; (2) a simple method of the polarization inversion for the ferroelectric single crystal which does not have a clear polarization inversion condition by a superimposed voltage method; and (3) a method of converting a polarization inversion area when the polarization inversion structure is made by the superimposed voltage method (column 2, lines 1-15 of Mizuuchi '495).

According to Mizuuchi '495, when the ferroelectric single crystalline films 51, 61, 62 are made of a ferroelectric single crystalline material which is difficult to form polarization inversion, a ferroelectric single crystalline substrate 1 which can easily form the polarization inversion and the ferroelectric single crystalline films 51, 61, 62 are connected. Accordingly, the polarization inversion structure formed in the ferroelectric single crystalline substrate 1 is transferred to the ferroelectric single crystalline films 51, 61, 62, so that the polarization inversion structure can be formed in the ferroelectric single crystalline films 51, 61, 62. Herewith, the above-mentioned object (1) can be obtained.

Also, according to Mizuuchi '495, when the polarization inversion condition of the ferroelectric single crystalline films 51, 61, 62 is not clear, by connecting the ferroelectric single crystalline substrate 1 which has a well-known polarization inversion condition with the ferroelectric single crystalline films 51, 61, 62, the polarization inversion structure formed in the ferroelectric single crystalline substrate 1 is transferred to the ferroelectric single crystalline films 51, 61, 62, and the polarization inversion structure can be formed in the ferroelectric single crystalline films 51, 61, 62. Herewith, the above-mentioned object (2) can be obtained.

Also, according to Mizuuchi '495, by connecting the ferroelectric single crystalline films 51, 61, 62 which have small (large) spontaneous polarization with the ferroelectric single crystalline substrate 1 which has large (small) spontaneous polarization, the respective polarization inversion area can be differential. Herewith, the above-mentioned object (3) can be obtained.

As stated above, the ferroelectric single crystalline films 51, 61, 62 in Mizuuchi '495 are necessary to be connected to the ferroelectric single crystalline substrate 1 by a diffusion bonding method or liquid-phase epitaxial method. Accordingly, the ferroelectric single crystalline films 51, 61, 62 are different from the "control layer formed in the first face of the ferroelectric single crystal" defined in claims 1 and 15 of the invention. Also, an object of Mizuuchi '495 is to provide the polarization inversion of the ferroelectric single crystalline films 51, 61, 62 themselves (for example, Examples 2-4; column 9, lines 19-25 of Mizuuchi '495), and the ferroelectric single crystalline films 51, 61, 62 do not function as the physical hindrance for physically suppressing the growth of the polarization inversion (domain) of the ferroelectric single crystalline substrate 1 to the uniform electrode 53. Therefore, the ferroelectric single crystalline films 51, 61, 62 do not correspond to the control layer defined in claims 1 and 15. Naturally, although the ferroelectric single crystalline films 51, 61, 62 in the Mizuuchi '495 are made of a ferroelectric substance material, the Mizuuchi '495 never show or suggest any defect density and degree of order of lattice points of the ferroelectric single crystalline films 51, 61, 62, and moreover, any magnitude correlation to fulfill the defect density and order of the lattice points of the ferroelectric single crystal.

As mentioned above, the method described in Mizuuchi '495 and the method described in claims 1 and 15 are different, and the present invention has novelty and inventive step relative to Mizuuchi '495.

In regard to claims 6 and 19, Examiner deemed that the ferroelectric single crystalline film 62 and an electrode 63 in Mizuuchi '495 correspond to the control layer in the claims 6 and 19. However, this accreditation is wrong.

Mizuuchi '495 assumes that the ferroelectric single crystalline films 61, 62 with more than two layers are connected to the ferroelectric single crystalline substrate 1. However, Mizuuchi '495 never shows that the ferroelectric single crystalline film 62 is formed on an electrode 63 side inside the ferroelectric single crystalline substrate 1, and includes the first region which has a larger defect density than that of the ferroelectric single crystalline substrate 1 / a lower degree of order of lattice points than that of the ferroelectric single crystalline substrate 1; and a second region which has an equal defect density than that of the ferroelectric single crystalline substrate 1 / an equal degree of order of lattice points than that of the ferroelectric single crystalline substrate 1. Also, Mizuuchi '495 never shows that the ferroelectric single crystalline film 62 functions as physical hindrance for the growth of the domain of the ferroelectric single crystalline substrate 1 in a perpendicular direction to a polarization direction.

Also, in the Action, it was held that claims 1 and 15 do not have novelty by Mizuuchi '515. Also, it was held that an insulating film 14 in Mizuuchi '515 corresponds to the control layer in claims 1 and 15. However, this accreditation is wrong. The insulating film 14 in Mizuuchi '515 is formed inside the ferroelectric single crystalline substrate 1, and not the control layer including the larger defect density than that of the

ferroelectric single crystalline substrate 1 / including the lower degree of order of the lattice points than that of the ferroelectric single crystalline substrate 1. Moreover, the insulating film 14 does not function as physical hindrance for the growth of the domain inverted region to a plane electrode 15.

An object of Mizuuchi '515 is to provide a method for manufacturing a polarization inversion part whose features such as depth, homogeneity, usable area and the like are improved (Abstract in Mizuuchi '515).

According to Mizuuchi '515, by accumulating the insulating film (SiO_2 film) 14 on a -C face of the substrate of the ferroelectric single crystal, the applied electric field is formed homogeneously, so that a periodical polarization inversion can be formed. Herewith, the above-mentioned object can be obtained. Since the insulating film 14 functions in such a way as to form the applied electric field homogeneously, insulation properties are necessary. The insulating film 14 like this is not the control layer formed inside the ferroelectric single crystalline substrate, and moreover, does not function as physical hindrance for the growth of the polarization inversion (domain) of the ferroelectric single crystal to the plane electrode 15. Therefore, the insulating film 14 does not correspond to the control layer defined in claims 1 and 15. Naturally, for the insulating film 14 in Mizuuchi '515, SiO_2 is only exemplified as a material including insulation properties. Mizuuchi '515 never shows or suggests any defect density and degree of order of lattice points of the insulating film 14, and moreover, any magnitude correlation to fulfill the defect density and order of the lattice points of the ferroelectric single crystal.

Also, Mizuuchi '515 discloses ion exchange on the surface in order to prevent disappearance of the polarization inversion part (for example, column 2, lines 28-47). However, an object of the

ion exchange as mentioned above is to stabilize the polarization inversion structure after the polarization inversion, and the ion exchange is conducted on the surface of the ferroelectric single crystal after the polarization inversion. Even with the above-mentioned technique and the insulating film 14 for forming the above-mentioned applied electric field homogeneously, the control layer defined in claims 1 and 15 of the present invention cannot be predicted, and the above-mentioned effect cannot be also obtained.

Therefore, the method described in Mizuuchi '515 and the method described in claims 1 and 15 are different, and also, claims 1 and 15 of the present invention have novelty and inventive step over Mizuuchi '515.

In regard to claim 5, claim 5 defines details of a process forming the control layer. More specifically, annealing is conducted in a special atmosphere. Herewith, the control layer wherein atoms are diffused out is formed in the first face. Examiner held that in Mizuuchi '515, the annealing is conducted when the polarization inverted regions are formed, and indicates that this corresponds to the annealing defined in claim 5. However, this opinion is wrong.

More specifically, although Mizuuchi '515 discloses the annealing whose object is to reduce the internal electric field (column 11, line 64 through column 12, line 14), and a proton-exchange heat treatment method (Embodiment 3) whose object is to stabilize the formed polarization inversion structure, both the annealing and the proton-exchange heat treatment method are different from the annealing for forming the above-mentioned control layer before the polarization inversion structure is formed. Naturally, the control layer wherein the atoms are diffused out cannot be obtained.

Examiner held that although Mizuuchi '495 does not disclose that the annealing is conducted in the special atmosphere, so that

the control layer wherein the atoms are diffused out is formed in the first face, the annealing can be easily conducted with the technology described in Mizuuchi '495. However, this opinion is wrong.

As explained above, Mizuuchi '495 discloses simply the ferroelectric single crystalline films 51, 61, 62, and they are different from the control layer defined in claim 1 in the present invention. Also, Mizuuchi '495 never indicates the object and function of the control layer defined in claim 1 in the invention, so that it is impossible to predict the annealing whose object is outward diffusion with the technology described in Mizuuchi '495.

In paragraph 11 of the Action, it was held that ion implantation can be easily conducted with the technology of Mizuuchi '495. Also, it was held that the ferroelectric single crystalline films 51, 61, 62 in Mizuuchi '495 include Zn.

As explained above, Mizuuchi '495 simply discloses the ferroelectric single crystalline films 51, 61, 62 including Zn in order to improve light damaging resistance, so that the ferroelectric single crystalline films 51, 61, 62 are different from the control layer defined in claim 15 or 18 of the invention. Also, the Mizuuchi '495 never indicates the object and function of the control layer defined in claim 15 or 18 of the invention. As a result, it is impossible to predict the ion implantation whose object is to control the order of the lattice points with the technology described in Mizuuchi '495.

As explained above, the features of the invention are not disclosed or suggested in the cited references. Even if the cited references are combined, claims of the invention are not obvious from the cited references.

Reconsideration and allowance are earnestly solicited.

Respectfully Submitted,
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